US009478383B2

(12) **United States Patent**
Lee et al.

(10) **Patent No.: US 9,478,383 B2**
(45) **Date of Patent: Oct. 25, 2016**

(54) **FAST SWITCH**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/666,021**

(22) Filed: **Mar. 23, 2015**

(65) **Prior Publication Data**

US 2015/0332884 A1 Nov. 19, 2015

(30) **Foreign Application Priority Data**

May 13, 2014 (KR) 10-2014-0057435

(51) **Int. Cl.**

H01H 33/00	(2006.01)
H01H 83/02	(2006.01)
H01H 33/16	(2006.01)
H01H 33/66	(2006.01)
H01H 71/24	(2006.01)

(52) **U.S. Cl.**

CPC ***H01H 83/02*** (2013.01); ***H01H 33/167*** (2013.01); ***H01H 33/66*** (2013.01); ***H01H 71/2409*** (2013.01)

(58) **Field of Classification Search**

USPC 361/115

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,319,121 A *	5/1967	Lee	....	H02H 3/20 218/140
3,411,038 A *	11/1968	Lee	....	H01H 33/66 218/140
2010/0165533 A1	7/2010	Lee et al.		
2013/0194703 A1	8/2013	Husband et al.		
2015/0108090 A1*	4/2015	Oates	....	H01H 33/596 218/10

(Continued)

FOREIGN PATENT DOCUMENTS

CN	203573898	4/2014
JP	2000-299041	10/2000
JP	2004-103318	4/2004

(Continued)

OTHER PUBLICATIONS

European Patent Office Application Serial No. 1561378.3, Search Report dated Oct. 22, 2015, 8 pages.

(Continued)

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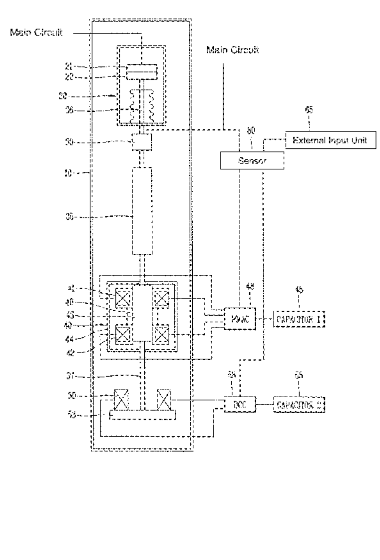
(57) **ABSTRACT**

The fast switch includes: a housing; a vacuum interrupter installed in the housing, connected to a main circuit, and configured to open and close the main circuit; a contact spring coupled to a mover of the vacuum interrupter, and configured to provide a contact force; an insulating rod connected to the contact spring; a permanent magnet actuator connected to a lower end of the insulating rod, and configured to provide a switching driving force; a first capacitor configured to provide a discharge current to a coil of the permanent magnet actuator; a driving coil connected to a lower end of the permanent magnet actuator; and a second capacitor configured to provide a discharge current to the driving coil.

8 Claims, 5 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2015/0206676	A1*	7/2015	Sato	H01H 33/666 335/136
2015/0332884	A1*	11/2015	Lee	H01H 83/02 361/42

FOREIGN PATENT DOCUMENTS

JP	2005-38630	2/2005
JP	2006-236773	9/2006
JP	2009-212024	9/2009
JP	2010-272296	12/2010
JP	2012-129143	7/2012
KR	10-2009-0071094	7/2009
KR	10-0928937	11/2009
KR	10-0955373	4/2010
KR	10-1280288	7/2013
KR	10-1315967	10/2013

OTHER PUBLICATIONS

Korean Intellectual Property Office Application Serial No. 10-2014-0057435, Office Action dated Nov. 18, 2015, 5 pages.

Japan Patent Office Application Serial No. 2015-089380, Office Action dated Feb. 16, 2016, 4 pages.

* cited by examiner

Fig. 1A

Prior Art

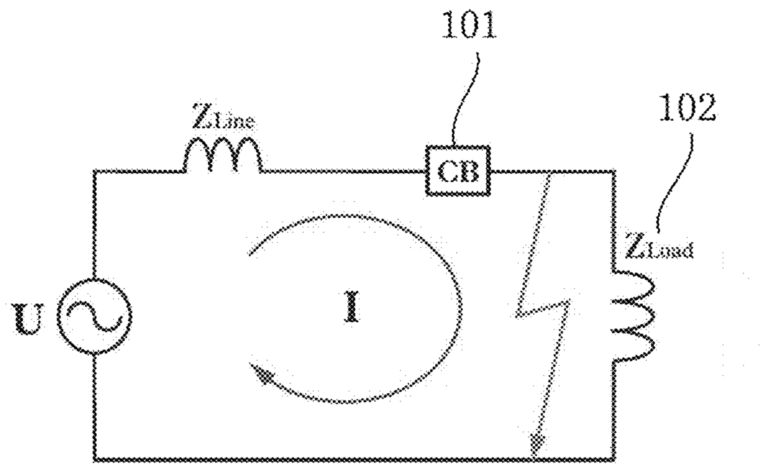


Fig. 1B

Prior Art

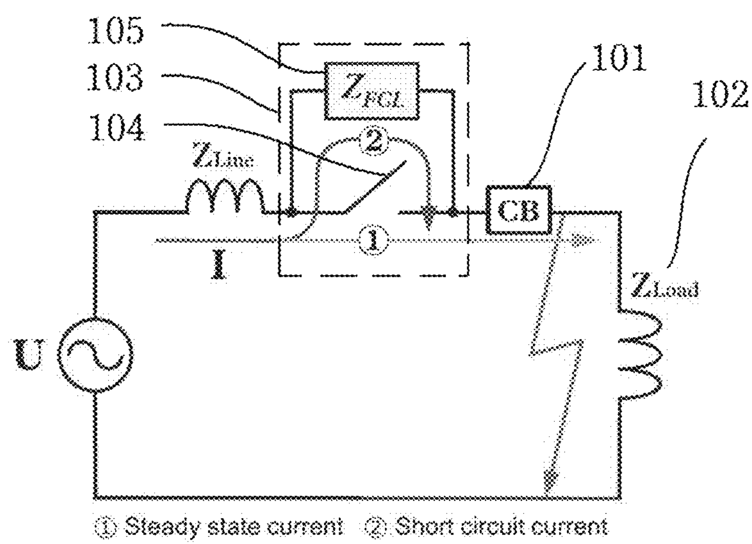


Fig. 2

Prior Art

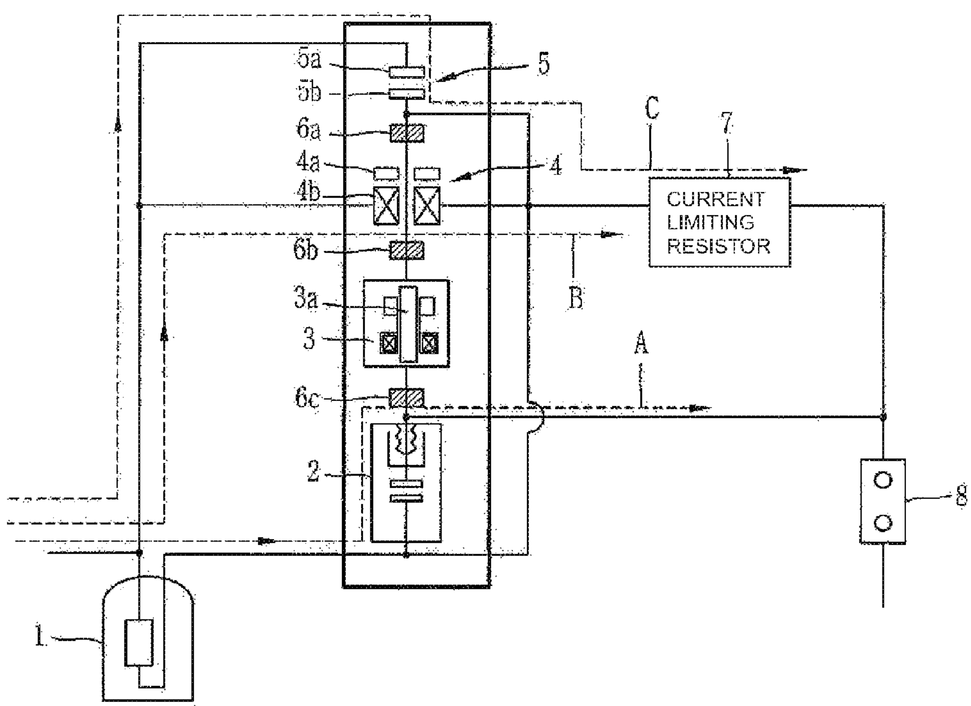


Fig. 3

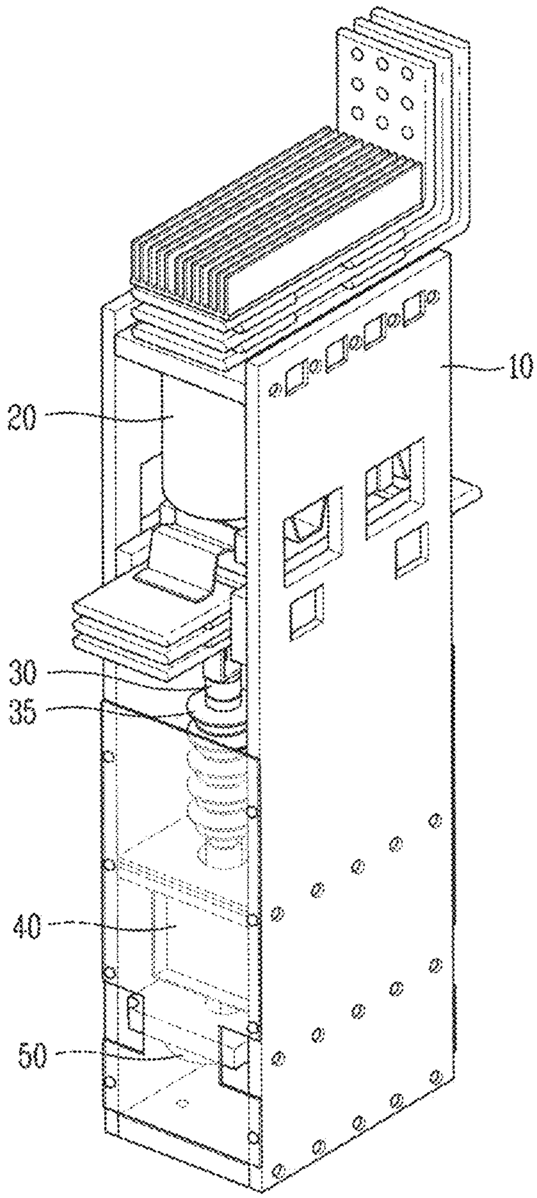
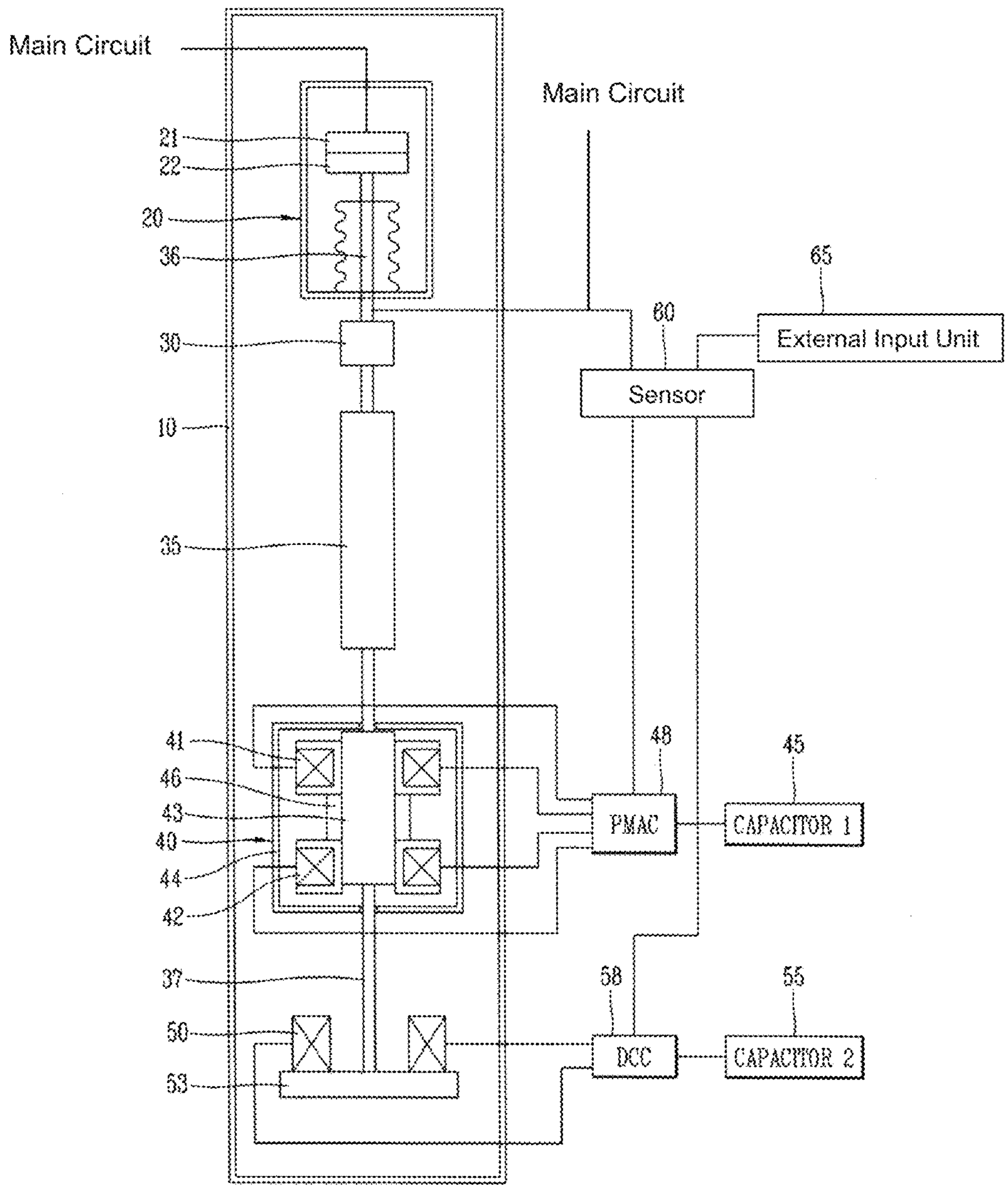


Fig. 4


Main Circuit
Main Circuit
21
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20
36
30
10
35
41
46
43
40
44
42
37
50
53
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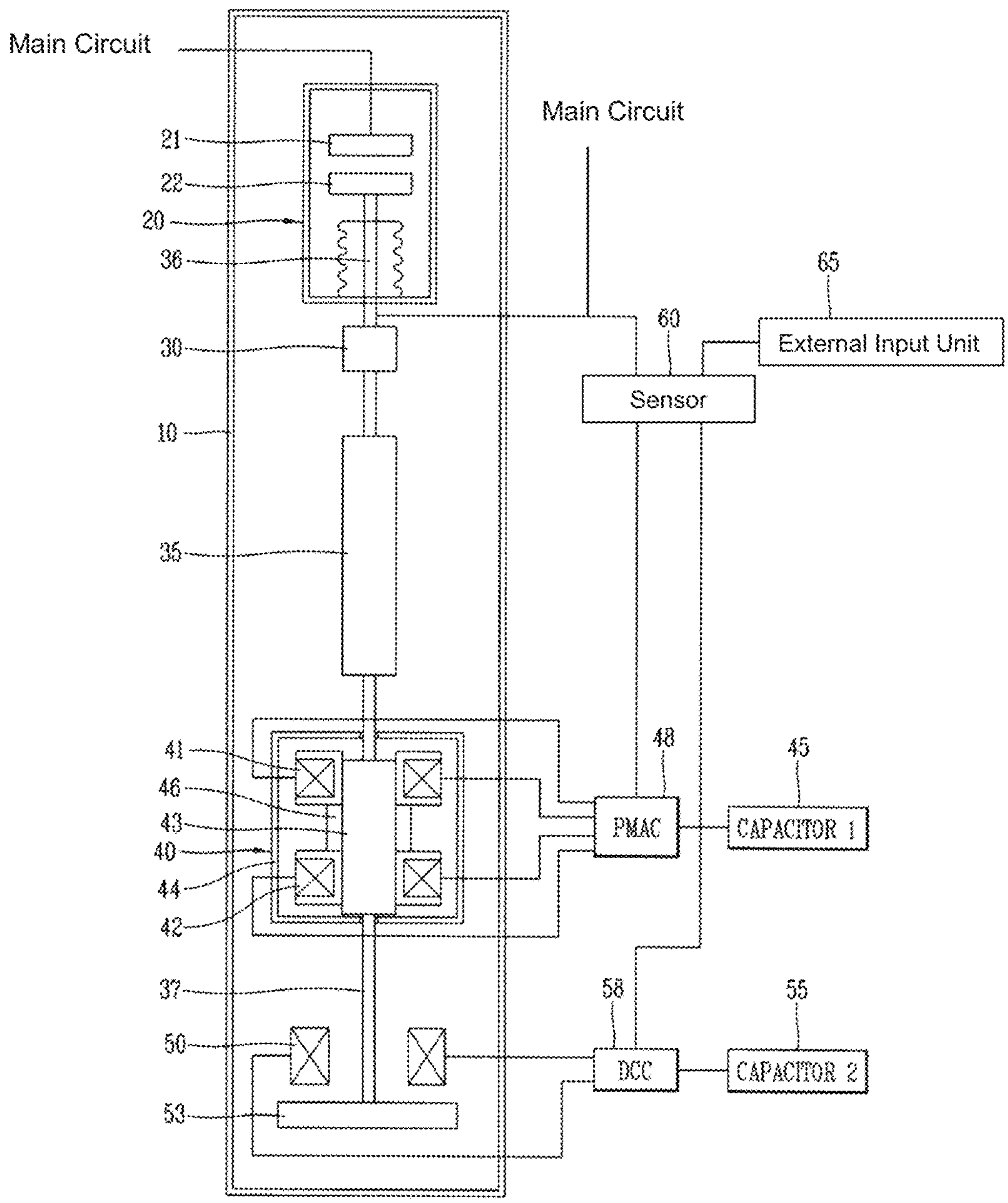
External Input Unit
60
Sensor
48
PMAC
45
CAPACITOR 1
58
DCC
55
CAPACITOR 2

Fig. 5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FAST SWITCH

CROSS-REFERENCE TO RELATED APPLICATION

Pursuant to 35 U.S.C. §119(a), this application claims the benefit of earlier filing date and right of priority to Korean Application No. 10-2014-0057435, filed on May 13, 2014, the contents of which is incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This specification relates to a fast switch, a component of a fault current limiter, and more particularly, a fast switch capable of constantly performing a main circuit interrupting operation, regardless of a size of a fault current, by interrupting a main circuit using a discharge current of an external capacitor.

2. Background of the Invention

Generally, a fault current limiter is a power device for protecting a power system by rapidly reducing a fault current when the large fault current occurs on the power system. That is, when a large fault current occurs on a power system, the fault current limiter reduces the fault current to a proper value or less than within a short time, thereby reducing a mechanical and thermal stress of the power device and enhancing reliability of the power system.

Such a fault current limiter may be compared with a general circuit breaker as follows. When a fault current occurs, the fault current limiter detects a breakdown rapidly and introduces a resistance (impedance). On the other hand, when a fault current occurs, the general circuit breaker separates or excludes a breakdown-occurred line from a power system by an interrupting operation. Further, it takes about 16 ms for the fault current limiter to operate after the fault current has occurred. On the other hand, it takes about 85 ms~120 ms for the general circuit breaker to operate after the fault current has occurred. Further, the fault current limiter is provided with a circuit for reducing a mechanical and thermal stress generated due to a breakdown, and for compensating for a low voltage. On the other hand, the general circuit breaker is not provided with such functions.

In a power system, when power of high quality is required and power has a large capacity, the fault current limiter is preferred owing to such advantages.

Main components of the fault current limiter include a fast fault detector (FFD), a fast switch (FS), and a current limiting resistor (CLR).

The fast fault detector (FFD) serves to rapidly-detect a breakdown occurring on a power system. When current exceeding a preset value is introduced, the FFD detects the current and thus transmits a signal to a fast switch controller.

The fast switch (FS) is composed of a main circuit contact for applying current and detouring a fault current, and a driving unit. And the fast switch (FS) serves to convert a fault current to a circuit of a current limiting resistor connected thereto in parallel.

The current limiting resistor (CLR) is not provided with current at a normal state, but is provided with a fault current when opening the fast switch (FS) by sensing a breakdown. The current limiting resistor (CLR) is a device for restricting a size of a fault current by its resistance.

FIGS. **1**A and **1**B illustrates a principle of a fault current limiter. FIG. **1**A illustrates a circuit before a fault current limiter is installed, i.e., a circuit where only a circuit breaker

is installed. FIG. **1**B illustrates a circuit where a fault current limiter and a circuit breaker are installed. When a fault current limiter is installed, a normal current (①) flows to a load device **102** via a circuit breaker **101** in a normal state. However, when a breakdown occurs, a fault current (②) flows to the load device **102** by making a detour to a current limiting resistor **105** as a fast switch **104** is open by a fault current limiter **103**.

In summary, a fast switch, a component of a fault current limiter, is connected to a current limiting resistor in parallel, so as to effectively control a fault current generated from a power system. The fast switch is a switching device for protecting the power system by rapidly detouring an occurred fault current to the current limiting resistor.

FIG. **2** illustrates a configuration of a fault current limiter in accordance with the conventional art. FIG. **2** illustrates a technique disclosed in Korean Registration Patent No. 10-0955373 ("Hybrid fault current limiter using superconducting device"). The conventional fault current limiter includes a superconducting device **1**; a vacuum interrupter **2** connected to a rear end of the superconducting device **1** in series; a rear-end circuit breaker **8** connected to a rear end of the vacuum interrupter **2** in series, and capable of switching a circuit of the power system toward a load side; a permanent magnet actuator **3** for providing a contact force to a movable contactor **2***b* of the vacuum interrupter **2** when a normal current flows to a power supply line of the power system; a fast switch **5** having a movable contact **5***b* connected to a mover **3***a* of the permanent magnet actuator **3** so as to be moveable in a synchronized manner; and a driving coil **4** driven to a closing position for conducting the fast switch **5** by being magnetized by a fault current when the superconducting device **1** is quenched, and driven to an opening position for interrupting the vacuum interrupter **2** by the permanent magnet actuator **3**.

An operation of the fault current limiter in accordance with the conventional art will be explained as follows.

In a normal state, current on a circuit flows along a conducting path (A). That is, the current is introduced along a power side line, and passes through the vacuum interrupter **2** via the superconducting device **1** of a non-resistance state, thereby being discharged to a load side through a rear-end circuit breaker **8**.

When a short-circuit current occurs on the circuit, resistance of the superconducting device **1** is drastically increased. Thus, the current is smaller than the resistance of the quenched superconducting device **1**, and flows along a conducting path (B). That is, the current passes through a current limiting resistor **7** and the rear-end circuit breaker **8**, via the driving coil **4** connected to the superconducting device **1** in parallel, thereby flowing to the load side. In this instance, since a repulsive plate **4***a* is vertically moved by a magnetic force generated at the driving coil **4**, the movable contactor **2***b* and a fixed contactor **2***a* of the vacuum interrupter **2** are separated from each other. Then, the movable contact **5***b* and a fixed contact **5***a* of the fast switch **5** come in contact with each other. Thus, the short-circuit current flowing along the conducting path (B) flows along a conducting path (C) connected to the load side via the closed fast switch, the current limiting resistor **7** and the rear-end circuit breaker **8**.

However, in the conventional art, a fault current (short-circuit current) is used when an opening operation is performed. This may cause an operation speed to be variable according to a size of the fault current. And, there may exist a proper fault current section for completion of the opening operation. That is, when a fault current is small, an electronic repulsive force is small. This may cause the fault current limiter not to operate. On the other hand, when a fault current is too large, the circuit is immediately re-closed by a mechanical repulsive force.

SUMMARY OF THE INVENTION

Therefore, an aspect of the detailed description is to provide a fast switch capable of constantly performing a main circuit interrupting operation, regardless of a size of a fault current, by interrupting a main circuit using a discharge current of an external capacitor.

To achieve these and other advantages and in accordance with the purpose of this specification, as embodied and broadly described herein, there is provided a fast switch, including: a housing; a vacuum interrupter installed in the housing, connected to a main circuit, and configured to open and close the main circuit; a contact spring coupled to a mover of the vacuum interrupter, and configured to provide a contact force; an insulating rod connected to the contact spring; a permanent magnet actuator connected to a lower end of the insulating rod, and configured to provide a switching driving force; a first capacitor configured to provide a discharge current to a coil of the permanent magnet actuator; a driving coil connected to a lower end of the permanent magnet actuator; and a second capacitor configured to provide a discharge current to the driving coil.

The coil may include an open coil configured to make the vacuum interrupter perform an opening operation; and a close coil configured to make the vacuum interrupter perform a closing operation.

The fast switch may further include a permanent magnet actuator controller formed between the permanent magnet actuator and the first capacitor, and configured to perform signal transmission and control.

The fast switch may further include a driving coil controller formed between the driving coil and the second capacitor, and configured to perform signal transmission and control.

A sensor may be provided between the main circuit and the permanent magnet actuator controller and the driving coil controller, and the sensor may be configured to transmit a signal generated from the main circuit to the permanent magnet actuator controller and the driving coil controller.

The fast switch may further include a repulsive plate provided below the driving coil, and vertically moving by an electronic repulsive force generated by a magnetic force of the driving coil.

A discharge current may flow to the open coil from the first capacitor, for prevention of a re-closing operation of the main circuit due to the electronic repulsive force of the repulsive plate when the vacuum interrupter performs an opening operation.

The first capacitor and the second capacitor may be provided inside or outside the housing.

The fast switch according to an embodiment of the present invention can have the following advantages.

Firstly, since the fast switch perform an opening operation and a closing operation by a discharge current generated from the first capacitor and the second capacitor installed inside or outside the housing, a circuit interrupting operation can be instantly performed regardless of a size of a fault current, when the main circuit is interrupted.

Secondly, since a capacity, a charging voltage, etc. of the first capacitor and the second capacitor can be controlled, a circuit interrupting operation can be performed at a user's desired operation speed.

Further scope of applicability of the present application will become more apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from the detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate exemplary embodiments and together with the description serve to explain the principles of the invention.

In the drawings:

FIGS. **1**A and **1**B illustrate a principle of a fault current limiter, in which FIG. **1**A illustrates a circuit where only a circuit breaker is installed, and FIG. **1**B illustrates a circuit where a fault current limiter and a circuit breaker are installed;

FIG. **2** is a view illustrating a configuration of a fault current limiter in accordance with the conventional art;

FIG. **3** is a perspective view of a fast switch according to an embodiment of the present invention;

FIG. **4** is a view illustrating a configuration of a fast switch according to an embodiment of the present invention, in which a vacuum interrupter is in a closed state; and

FIG. **5** is a view illustrating a configuration when the vacuum interrupter of FIG. **4** is in an open state.

DETAILED DESCRIPTION OF THE INVENTION

Description will now be given in detail of preferred configurations of a fast switch according to an embodiment of the present invention, with reference to the accompanying drawings.

FIG. **3** is a perspective view of a fast switch according to an embodiment of the present invention. FIG. **4** is a view illustrating a configuration of a fast switch according to an embodiment of the present invention, in which a vacuum interrupter is in a closed state. FIG. **5** is a view illustrating a configuration when the vacuum interrupter of FIG. **4** is in an open state.

A fast switch according to an embodiment of the present invention includes a housing **10**; a vacuum interrupter **20** installed in the housing **10**, connected to a main circuit, and configured to open and close the main circuit; a contact spring **30** coupled to a movable portion of the vacuum interrupter **20**, and configured to provide a contact force; an insulating rod **35** connected to the contact spring **30**; a permanent magnet actuator **40** connected to a lower end of the insulating rod **35**, and configured to provide a switching (opening/closing) driving force; a first capacitor **45** configured to provide a discharge current to a close coil **41** of the permanent magnet actuator **40**; a driving coil **50** connected to a lower end of the permanent magnet actuator **40**; and a second capacitor **55** configured to provide a discharge current to the driving coil **50**.

The housing **10** may be formed to have a box shape where front and rear surfaces are open. The housing **10** is configured to accommodate therein various types of components of the fast switch according to an embodiment of the present invention.

The vacuum interrupter **20** includes a fixed contact **21**, and a movable contact **22** configured to contact or to be separated from the fixed contact **21**. When a normal current flows, the fixed contact **21** and the movable contact **22** are in a contacted state. However, when a fault current occurs, the fixed contact **21** and the movable contact **22** are separated from each other, such that the fault current detours to a current limiting resistor (not shown). Under such a configuration, an accident can be prevented and a power system can be protected.

The contact spring **30** provides a contact force to the movable portion of the vacuum interrupter **20**, thereby enhancing a conducting function. Further, the contact spring **30** compensates for loss due to repeated switching operations, thereby maintaining a constant interrupting operation.

The permanent magnet actuator **40** includes a frame **44**, a close coil **41** installed in the frame **44**, an open coil **42**, a permanent magnet **46**, and a mover **43** moved by a magnetic force generated from the close coil **41** and the open coil **42**. The permanent magnet actuator **40** is provided with the close coil **41** and the open coil **42**, and allows the vacuum interrupter **20** to perform a switching operation. More specifically, for an opening operation, the permanent magnet actuator **40** performs a latch function to prevent a re-closing phenomenon. On the other hand, for a closing operation, the permanent magnet actuator **40** provides a driving force. A discharge current, generated from the first capacitor **45** which is to be explained, selectively flows to the close coil **41** or the open coil **42**.

The first capacitor **45** is connected to each of the close coil **41** and the open coil **42** of the permanent magnet actuator **40**, thereby providing a discharge current thereto.

A permanent magnet actuator controller (PMAC) **48** may be installed between the permanent magnet actuator **40** and the first capacitor **45**. The permanent magnet actuator controller (PMAC) **48** may perform signal transmission and control with respect to the first capacitor **45**. For instance, the permanent magnet actuator controller (PMAC) **48** may determine whether current discharged from the first capacitor **45** is made to flow to the close coil **41** or the open coil **42**.

The driving coil **50** provides a driving force required for the vacuum interrupter **20** to perform an opening operation, together with a repulsive plate **53**.

The second capacitor **55** is connected to the driving coil **50**, thereby providing a discharge current.

A driving coil controller (DCC) **58** may be installed between the driving coil **50** and the second capacitor **55**. The driving coil controller (DCC) **58** may perform signal transmission and control with respect to the second capacitor **55**.

The repulsive plate **53** is installed at a lower end of a lower moving rod **37**, and is vertically moved by an electronic repulsive force generated by a magnetic force of the driving coil **50**.

An upper moving rod **36** coupled to the movable contact **22** of the vacuum interrupter **20**, the insulating rod **35** installed between the vacuum interrupter **20** and the permanent magnet actuator **40**, the mover **43** of the permanent magnet actuator **40**, and the lower moving rod **37** installed between the permanent magnet actuator **40** and the repulsive plate **53** are connected to one another in series, thereby being moved in an integral manner.

The fast switch according to an embodiment of the present invention may further include a sensor **60**. The sensor **60** may transmit a signal, as one end thereof is connected to a main circuit, and another end thereof is connected to the driving coil controller **58** and the permanent magnet actuator controller **48**. For instance, the sensor **60** may receive a fault current signal generated from the main circuit, and may transmit the received fault current signal to the driving coil controller **58** and the permanent magnet actuator controller **48**. The fast switch according to an embodiment of the present invention may further include an external input unit **65** configured to receive a manual input signal transmitted from outside.

An operation of the fast switch according to an embodiment of the present invention will be explained.

Firstly, an instance, where a closing operation of the vacuum interrupter is performed such that current flows on the main circuit in a normal state, will be explained. Current is discharged from the first capacitor **45** by a manual input or when a preset time lapses in the circuit. The current discharged from the first capacitor **45** generates a magnetic force while flowing on the close coil **41** of the permanent magnet actuator **40**. The mover **43** is upward moved by a magnetic force generated from the close coil **41**. As the mover **43** is moved, the insulating rod **35** and the upper moving rod **36** connected to the mover **43** in series are upward moved in an interworking manner. As a result, the movable contact **22** is also upward moved to contact the fixed contact **21**, so that the main circuit is in a conducted state.

In this instance, the contact spring **30** provides a contact force to the movable contact **22**, so that the movable contact **22** can contact the fixed contact **21** with a strong force. Further, the contact spring **30** allows the movable contact **22** and the fixed contact **21** to stably contact each other, even when the movable contact **22** and the fixed contact **21** are abraded or compressed by being repeatedly used.

The permanent magnet actuator controller **48** performs control between the first capacitor **45** and the permanent magnet actuator **40**. That is, the permanent magnet actuator controller **48** controls the first capacitor **45** to discharge current, by a signal of the main circuit input from the sensor **60**, a manual signal input from the external input unit **65**, or a signal internally set. Further, the permanent magnet actuator controller **48** may set a discharge time, a current amount, etc. with respect to current discharged from the first capacitor **45**.

Next, will be explained a case where the vacuum interrupter performs an opening operation (trip operation) when a fault current occurs, such that the main circuit is interrupted and the fault current is made to detour to an auxiliary circuit (not shown) to which a current limiting resistor (not shown) is connected. Current is discharged from the second capacitor **55** when a fault current flows on the main circuit, or by a manual input. The current discharged from the second capacitor **55** generates a magnetic force while flowing on the driving coil **50**. The repulsive plate **53**, which receives an electronic repulsive force by the magnetic force generated from the driving coil **50**, is downward moved. As the repulsive plate **53** is moved, the lower moving rod **37**, the mover **43**, the insulating rod **35**, and the upper moving rod **36** which are connected to the repulsive plate **53** in series are downward moved in an interworking manner. As a result, the movable contact **22** is separated from the fixed contact **21**, and the main circuit is interrupted.

The driving coil controller **58** performs signal transmission and control between the second capacitor **55** and the driving coil **50**. That is, as a signal of the main circuit input from the sensor **60** or a manual signal introduced from the external input unit **65** is transmitted, current of the second capacitor **55** is discharged. Further, a discharge time, a current amount, etc. with respect to current discharged from the second capacitor **55** may be set.

For prevention of a re-closing phenomenon occurring due to a repulsive force of the repulsive plate **53** during a trip operation, a discharge current from the first capacitor **45** flows to the open coil **42** of the permanent magnet actuator **40**. As a result, the mover **43** is downward moved.

The fast switch according to an embodiment of the present invention performs an opening operation and a closing operation by a discharge current generated from the first capacitor **45** and the second capacitor **55**. Thus, a circuit interrupting operation can be constantly performed regardless of a size of a fault current, when the main circuit is interrupted.

Further, since a capacitance of the capacitor, a charging voltage, etc. are controllable, an interrupting operation can be performed at a user's desired operation speed.

Further, since the fast switch of the present invention has a shorter driving time than a fast switch of a mechanical mechanism, a fault current can be detoured within a ½ cycle.

As the present features may be embodied in several forms without departing from the characteristics thereof, it should also be understood that the above-described embodiments are not limited by any of the details of the foregoing description, unless otherwise specified, but rather should be construed broadly within its scope as defined in the appended claims, and therefore all changes and modifications that fall within the metes and bounds of the claims, or equivalents of such metes and bounds are therefore intended to be embraced by the appended claims.

What is claimed is:

1. A fast switch, comprising:

a housing;

a vacuum interrupter installed in the housing, connected to a main circuit, and configured to open and close the main circuit;

a contact spring coupled to a mover of the vacuum interrupter, and configured to provide a contact force;

an insulating rod connected to the contact spring;

a permanent magnet actuator connected to a lower end of the insulating rod, and configured to provide a switching driving force;

a first capacitor configured to provide a discharge current to a coil of the permanent magnet actuator;

a driving coil connected to a lower end of the permanent magnet actuator; and

a second capacitor configured to provide a discharge current to the driving coil.

2. The fast switch of claim **1**, wherein the coil includes:

an open coil configured to allow the vacuum interrupter to perform an opening operation; and

a close coil configured to allow the vacuum interrupter to perform a closing operation.

3. The fast switch of claim **1**, further comprising a permanent magnet actuator controller formed between the permanent magnet actuator and the first capacitor, the permanent magnet actuator controller configured to perform signal transmission and control.

4. The fast switch of claim **1**, further comprising a driving coil controller formed between the driving coil and the second capacitor, the driving controller configured to perform signal transmission and control.

5. The fast switch of claim **2**, further comprising a repulsive plate provided below the driving coil, the repulsive plate vertically moving by an electronic repulsive force generated by a magnetic force of the driving coil.

6. The fast switch of claim **5**, wherein a discharge current flows to the open coil from the first capacitor, for prevention of a re-closing operation of the main circuit due to the electronic repulsive force of the repulsive plate when the vacuum interrupter performs an opening operation.

7. The fast switch of claim **4**, wherein a sensor is provided between the main circuit and the permanent magnet actuator controller and the driving coil controller, the sensor configured to transmit a signal generated from the main circuit to the permanent magnet actuator controller and the driving coil controller.

8. The fast switch of claim **1**, wherein the first capacitor and the second capacitor are provided inside or outside the housing.

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